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C. J. CALBICK
SPACE CURRENT DEVICE EMPLOYING
MUTUALLY BOMBARDED ELECTRODES
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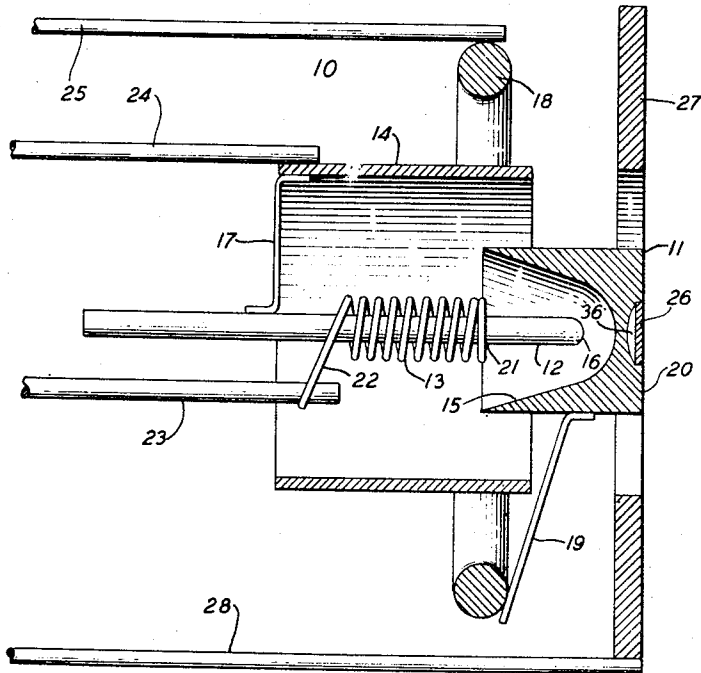


FIG. 1

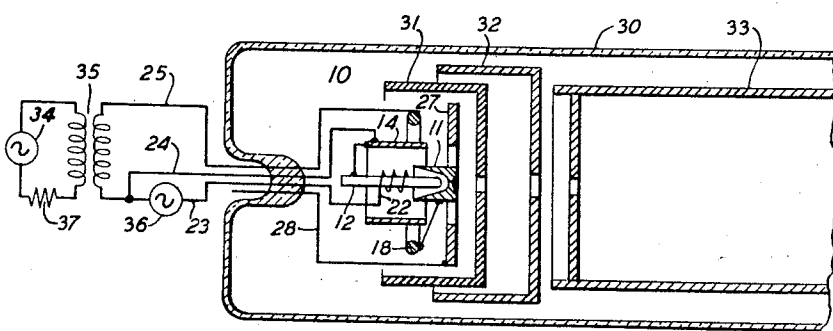


FIG. 2

INVENTOR
C. J. CALBICK

BY

Hugh S. Wertz
ATTORNEY

UNITED STATES PATENT OFFICE

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SPACE CURRENT DEVICE EMPLOYING MUTUALLY BOMBARDED ELECTRODES

Chester J. Calbick, Chatham, N. J., assignor to
Bell Telephone Laboratories, Incorporated, New
York, N. Y., a corporation of New York

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This invention relates to electrode structures for vacuum tubes, and more particularly to electron emitting structures suitable for use in cathode ray television receiver tubes.

It is an object of this invention to increase the emission density and stability of cathode structures for cathode ray tubes.

It is another object of this invention to utilize in an electrode structure for a cathode ray tube the principle of mutual bombardment in vacuo of two emitting electrodes.

It has been heretofore proposed to utilize in a vacuum tube the principle of mutual bombardment in vacuo of two electron emitting electrodes. If two electron emitting electrodes are enclosed in an evacuated space, and a suitable alternating voltage is applied between them, they will, if one is heated sufficiently by a starting filament or other means, each emit enough electrons to bombard the other, so that the initial heating mechanism can be dispensed with. Various structures making use of this principle are disclosed in Patent 1,705,377, issued March 12, 1929, to E. Y. Robinson. The present invention is concerned with a specific cathode structure for cathode ray tubes which makes use of this principle and yields a high electron emission density.

In accordance with the invention, there is provided, by way of example, an electrode structure for a cathode ray tube comprising a cathode member having a substantially flat electron emitting outer surface and an electron emitting inner surface which is a surface of a revolution, such as one which is a paraboloid or one which includes a portion of the inner surface of a hollow sphere, an auxiliary cathode having a rounded or semispherical electron emitting end adjacent the inner surface of the cathode member and having a starting filament near or around it, and a cylinder surrounding the auxiliary cathode to concentrate electrons from the starting filament upon the rim of the open end (away from the flat surface) of the cathode member. The cathode member is preferably of tantalum and the auxiliary member of tungsten. Parts of the flat surface of the cathode member can be carburized if desired to make the treated portions more inactive than other portions thereof. An alternating potential is applied between the cathode member and the auxiliary cathode. The starting filament is energized to cause the inner surface of the cathode member to be bombarded with electrons. The electrons emitted by this inner surface bombard the auxil-

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ary cathode during one-half of the cycle and when this emission has reached a certain value, this auxiliary cathode becomes sufficiently heated to bombard the cathode member (causing emission from its flat outer surface when it has heated sufficiently) during the other half of the cycle. At a properly selected time after the establishment of mutual bombardment, the starting filament is turned off. This electrode structure can be used with suitable anodes to produce a focused beam of electrons in a cathode ray tube in accordance with well-known practice.

The invention will be more readily understood by referring to the following description taken in connection with the accompanying drawings forming a part thereof in which:

Fig. 1 is an enlarged cross-sectional view of electrode structure in accordance with the invention; and

Fig. 2 shows a portion of a cathode ray tube in which the electrode structure of Fig. 1 is mounted.

Referring more particularly to the drawing, Fig. 1 shows, by way of example for purposes of illustration, an electrode structure 10 capable of emitting electrons with high electron emission density. The electrode structure 10 comprises a cathode 11, an auxiliary cathode 12, a starting filament 13, and a cylinder 14 surrounding the members 12 and 13 and serving to concentrate electrons from the starting filament upon the rim of the open end of the cathode 11.

The cathode 11 is made from a cylindrical piece of a refractory metal such as tungsten, molybdenum, osmium and tantalum which emit thermionic electrons adequately at temperatures considerably below their melting points. Other metals which melt before producing appreciable electron emission densities (such as silver, gold, platinum, etc.) cannot be used for this purpose unless the surfaces thereof are treated in some manner (for example, by coating with oxides of barium and strontium) to render them thermionically more active. The interior of the cathode 11 is hollowed out to produce a paraboloidal inner surface 15 (or one which includes a portion of the inner surface of a hollow sphere).

The auxiliary cathode 12 is a post of a refractory metal (such as that of which the cathode 11 is made) and the end thereof projects into the cavity of the cathode 11. The tip 16 of the auxiliary cathode 12 is preferably rounded as shown in the drawing. Connected to the auxiliary cathode 12 by the support member 17 is the cylinder 14, preferably of molybdenum, which sur-

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rounds the auxiliary cathode 12 and the end of the cathode 11 near the member 12 and serves to concentrate electrons from the starting filament 13 upon the rim of the open end 15 of the cathode 11. The cylinder 14 also serves to prevent bombardment, especially during starting, of the ring 18 which supports the cathode 11 by means of a plurality of support members 19. The cylinder 14 also acts to a limited degree as a radiation shield, and also as a grid to prevent electrons from the post 12 being drawn into the space to the right of the cathode 11 whose right-hand surface 20 is furnishing the beam current of the cathode ray tube. The starting filament 13 comprises a coil of wire of a suitable material such as tungsten, surrounding and having one end 21 connected to the post 12 and having the other end 22 thereof connected to a terminal 23. Heating current is applied to the starting filament 13 by means of the terminal 23 and the terminal 24 which is connected to the end 21 of the filament 13 by means of the cylinder 14, the connector 17 and the rod 12. The ring 18 is fastened to terminal 25 which is thus electrically connected to the cathode 11 by means of this ring and support 19.

The outer surface 20 of the cathode 11 preferably has a composited surface. By "composite surface" is meant one whose electron emission varies locally over the surface in a controlled manner. This control may be by means of different materials or by localized chemical treatment which produces surface areas of different thermionic properties or which affects their thermal emissive power so that their local temperature is changed or it may be by thermal means (such as those disclosed in the Robinson patent, for example) or by a combination of one or more of these. In some applications it is desirable or essential that the emitting area be sharply defined geometrically or that a portion of the area should not emit electrons. For example, if on the flat end 20 of the cathode 11 (which by way of example is of tantalum or some other thermionically more active material, such as carbided, thoriated tungsten), a shallow depression 26 is ground and if a small thin disc 26 of tungsten is then welded or otherwise fastened in this shallow hole, the center of the cathode is thermionically inactive compared to the rest of the cathode surface. The result is an annular emitting area on the end of the cathode 11. Obviously, the principle of the example can be generalized (within practical limits) to cover the making of composite emitting surfaces the activity of which differs in local areas in any desired manner. If desired, the outer surface of the tungsten disc 26 can be sandblasted to greatly increase its emissivity. If, in addition, this shallow hole 26 is made slightly concave and the tungsten disc 26 is welded to the tantalum cathode 11 only at its periphery, the tungsten is radiatively cooled to a temperature much below that of the tantalum. This example is given to illustrate the general principle that effects due to variation of emissivity can be increased by some degree of design control of thermal conduction.

It has been discovered that if the cathode 11 and auxiliary cathode 12 are made of different materials, superior operating results are produced. By way of example, the cathode 11 can be made of tantalum and the auxiliary cathode 12 of tungsten.

Surrounding the cathode 11 is the annular ring

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27 which can be placed at the same potential as the cathode 11 by means of the terminal 28 (or at some other potential, if desired). If placed at the same potential, the field lines in the vicinity of the cathode are more nearly parallel to the axis if the first member of the electron optical system following the cathode is a disc. The surrounding ring 27 is not necessarily flat. It can be conical, paraboloidal or any other convenient shape (electron optics, in general, requires that these shapes should be axially symmetric. Moreover, the surface 11 in the cathode need not be flat but can, for example, be a concave spherical surface for electron optical reasons.

Reference will now be made to Fig. 2 wherein the cathode structure 10 of Fig. 1 is shown positioned in the butt end of a cathode ray tube 30. Associated with the cathode structure 10 can be any suitable electron optical arrangement. By way of example, positioned parallel to and adjacent the annular electrode 27 is a modulating electrode 31 followed by a first accelerating anode 32 which in turn is followed by a second accelerating anode cylinder 33. Members similar to the electrodes 31, 32 and 33 are shown in connection with a cathode having a flat surface in Patent 2,260,313 issued October 28, 1941 to F. Gray and the operation of such electrode members is also disclosed in the Gray patent. It is obvious, however, that the cathode structure 10 shown in Fig. 1 is suitable for use in a variety of electron gun structures. In some of these structures, the annular member 27 surrounding the cathode can be omitted or placed to the right of the plane of the surface 20.

A source 34 of alternating voltage is connected by means of the transformer 35 to the terminals 25 and 24 or, in other words, between the cathode 11 and the auxiliary cathode 12. The frequency and voltage of the wave applied to the terminals 25 and 24 are not critical; by way of example, they can be 60 cycles and 1000 volts respectively. An alternating source 36 of the order of 6 volts at 60 cycles is connected between the terminals 24 and 23 to provide heating current for the starting filament 13. The members 31, 32 and 33 are placed at appropriate potentials to form and accelerate a cathode ray beam. Suitable potentials for these members are set forth in the Gray patent. Connected in either the primary or secondary circuit of the transformer 35 (by way of example, it has been shown in the primary circuit) is a resistance 37, the purpose of which will be described more fully below.

The operation of the arrangement shown in Figs. 1 and 2 will now be described. Heating current is applied to the starting filament 13 to cause it to emit electrons to the surface 15 of the cathode 11 when the phase of the high voltage alternating wave from the source 34 and the transformer 35 is such that the cathode 11 is positive with respect to the starting filament and the auxiliary cathode 12. These electrons heat the cathode 11 and, when its temperature has been raised sufficiently high, it also emits electrons which, during the opposite phase of the alternating wave when the auxiliary cathode 12 is positive with respect to the cathode 11, bombard the auxiliary cathode 12 and raise its temperature sufficiently high so that it also emits electrons. These electrons are in effect added to those emitted by the starting filament, so that the temperature of the cathode rises more rapidly, causing rapidly increasing thermionic emission of electrons which, on the alternate half cycle,

bombard the auxiliary cathode 12, causing its temperature also to rise rapidly and its emission to increase. When this emission has reached a certain value, it is sufficient to maintain the temperature of the cathode 11 without electrons from the starting filament 13. At this point, it can be said that mutual bombardment is established and the current in the starting filament is turned off by any suitable circuit. One such starting circuit is disclosed in the Robinson patent mentioned above. The temperature at which the cathode 11 operates can be adjusted to any value above a certain minimum by control of the magnitude of the alternating bombarding voltage. The minimum value is determined by the geometry of the mutual bombardment space. At any value of bombarding voltage above a certain minimum, the temperatures of the cathode 11 and auxiliary cathode 12 will rise until the bombarding current is limited by space charge. When the applied bombarding voltage is symmetrical, i. e. where it has the same amplitude in both directions, the temperatures will rise until the bombarding current from the auxiliary cathode 12 to the cathode 11 is thus limited. The applied bombarding voltage may have different amplitudes in the two directions, as may be secured, for example, by inserting a copper oxide rectifier in the primary circuit of the transformer 35 supplying voltage to the terminals 25 and 24. In particular, if the amplitude of the alternating bombarding voltage applied during the half cycles when the auxiliary cathode 12 is positive with respect to the cathode 11 is much less than that applied during the alternate half cycles, the temperature will rise until the bombarding current from cathode 11 to the auxiliary cathode 12 is limited by space charge, the bombarding current in the reverse direction being limited by the temperature of the auxiliary cathode 12. The importance of this application of asymmetrical bombarding voltage is that it reduces the minimum temperature of stable operation. A second desirable effect is that heating of the cathode 11 tends to be localized around its closed end 20, since the right-hand end of auxiliary cathode 12 is at a much higher temperature than its left-hand end, because of heat loss due to thermal conduction and radiation. Because of this localized heating, the useful end 20 of cathode 11 is at a higher temperature than the open end.

The minimum temperature of stable operation can be further reduced by insertion of the series resistance 37 in either the primary or secondary circuit of the transformer 35 supplying the bombarding voltage. In general, with an asymmetrical structure such as the mutual bombardment cathode of Fig. 1, best operation is secured by using a compensating asymmetry of either voltage or material or both. When the auxiliary cathode is tungsten and the cathode is tantalum, for example, effects are obtained similar to those obtained by an asymmetrical voltage wave when the two mutually bombarded cathodes are of the same material.

For a particular structure such as that of Fig. 1, an appropriate circuit can be designed to yield a low minimum temperature. This has the advantage that the life of the post constituting the auxiliary cathode 12 is greatly increased compared with that under conditions of simple space-charge stabilization. Above the minimum operating temperature, the temperature can be simply controlled to any value below the melting

point of the cathode 11 by control of the voltage applied to the primary of the transformer 35.

Other advantages and features of mutual bombardment are: (1) cathodes of large or small area massive enough to give long life and sufficient mechanical strength can be heated to high temperature with a resultant very high electron emission density; (2) this heating is done by high voltage and relatively small bombarding current which is in sharp contrast to conductively heated cathodes of large area; (3) as a consequence of the small current and also the symmetrical distribution, magnetic fields due to heating are extremely small (very much smaller than in the best indirectly heated cathodes); (4) by proper control methods (some of which have been set forth above) absolute stability and freedom of temperature adjustment within the mutual bombardment region can be achieved; (5) if high emission density is not required, the temperature range of stable operation is sufficient to permit extremely long life by lowering the temperature; (6) long life can be achieved by making the auxiliary cathode sufficiently massive and by operating at a sufficiently low temperature; (7) in case it is desired to subject cathodes to chemical manipulation, as in thoriation and carburization processes, operating conditions can be specified by which this action can be achieved which is in considerable contrast to directly heated, radiatively shielded cathodes; (8) the power source required and auxiliary starting equipment are simple; (9) wide latitude of geometrical design for the achievement of special purposes is possible and, in particular, adequate shielding either for radiative purposes or to prevent bombardment current from entering the useful region of the electron discharge device is easily achieved; (10) composite cathodes and composite cathode surfaces (such as that produced in the front surface of the cathode 11 by the insert disc 26) can be used, such cathodes and cathode surfaces being important for special applications; (11) the cathode can act as a getter, producing an exceptionally high vacuum as the tube operates, tantalum cathodes probably being the best for this use; (12) "ion spots" can be eliminated from the fluorescent screens of cathode ray oscillograph or television tubes because a pure metal cathode which does not emit appreciable numbers of negative ions (the cause of the ion spots) can be used instead of an oxide-coated cathode which emits large quantities of such ions; and (13) mutual bombardment can also be used in the production of high temperature per se, as is required in a high temperature vacuum furnace. The principal disadvantage of the mutual bombardment method is the fluctuation of temperature over the cycle of its bombardment but this is of small importance when the useful current is space-charge limited as in most electron discharge devices. In any event the fluctuation is small and can be reduced by increasing the mass per unit area of the cathode 11.

Various modifications of the embodiment described above can be made without departing from the spirit of the invention the scope of which is indicated in the claims.

What is claimed is:

1. A space current device comprising an evacuated container enclosing a first thermionic electrode member having a first electron emitting surface and a second electron emitting surface, said second surface including a concave surface, and a second thermionic electrode, at least a portion

of the electron emitting area of said second electrode being positioned within the space bounded by said concave surface, and means for applying an alternating potential wave between said first and second electrode members.

2. The combination of elements as in claim 1 in which said concave surface is paraboloidal.

3. A space current device comprising an evacuated container enclosing a cathode member having a first electron emitting surface and a second electron emitting surface, said second surface being concave, and an auxiliary cathode member comprising a metal rod having an end thereof adjacent said second surface, at least a portion of the electron emitting area of said auxiliary cathode member being positioned within the space bounded by said concave surface.

4. A space current device comprising an evacuated container enclosing a cathode member having a first electron emitting surface and a second electron emitting surface, said second surface being concave, an auxiliary cathode member comprising a metal rod having an end thereof adjacent said second surface, at least a portion of the electron emitting area of said auxiliary cathode member being positioned within the space bounded by said concave surface, and a shielding member surrounding at least a portion of said auxiliary cathode and said cathode member.

5. A space current device comprising an evacuated container enclosing a cathode member having a first electron emitting surface and a second electron emitting surface, said second surface being concave, an auxiliary cathode member comprising a metal rod having an end thereof adjacent said second surface, at least a portion of the electron emitting area of said auxiliary cathode member being positioned within the space bounded by said concave surface, and a starting filament surrounding said auxiliary cathode.

6. A space current device comprising an evacuated container enclosing a cathode member having a first electron emitting surface and a second electron emitting surface, said second surface being concave, an auxiliary cathode member comprising a metal rod having an end thereof adjacent said second surface, at least a portion of the electron emitting area of said auxiliary cathode member being positioned within the space bounded by said concave surface, and an annular member surrounding that portion of said cathode member remote from said auxiliary cathode member.

7. A space current device comprising an evacuated container enclosing a cathode member having a first electron emitting surface and a second electron emitting surface, said second surface being concave and an auxiliary cathode member comprising a metal rod having an end thereof adjacent said second surface, at least a portion of the electron emitting area of said auxiliary cathode member being positioned within the space bounded by said concave surface, said cathode and said auxiliary cathode being of different refractory metals which emit thermionic electrons at temperatures considerably below their melting points.

8. A space current device comprising an evacuated container enclosing a cathode member hav-

ing a first electron emitting surface and a second electron emitting surface, said second surface being paraboloidal and said first surface being flat, and an auxiliary cathode member comprising a metal rod having a rounded end thereof adjacent said second surface, at least a portion of the electron emitting area of said auxiliary cathode member being positioned within the space bounded by said paraboloidal surface and the longitudinal axis of the auxiliary cathode coinciding with the longitudinal axis of the paraboloidal surface.

9. A space current device comprising an evacuated container enclosing a cathode member having a first electron emitting surface and a second electron emitting surface, said second surface being concave, and an auxiliary cathode member comprising a metal rod having an end thereof adjacent said second surface, at least a portion of the electron emitting area of said auxiliary cathode member being positioned within the space bounded by said concave surface, said cathode being made of tantalum and said auxiliary cathode being made of tungsten.

10. A space current device comprising an evacuated container enclosing a cathode member having a first electron emitting surface and a second electron emitting surface, said second surface being concave, and an auxiliary cathode member comprising a metal rod having an end thereof adjacent said second surface, at least a portion of the electron emitting area of said auxiliary cathode member being positioned within the space bounded by said concave surface, said cathode having a first surface the electron emission of which varies locally thereover in a controlled manner.

11. A space current device comprising an evacuated container enclosing a cathode member having a first electron emitting surface and a second electron emitting surface, said second surface being concave, and an auxiliary cathode member comprising a metal rod having an end thereof adjacent said second surface, at least a portion of the electron emitting area of said auxiliary cathode member being positioned within the space bounded by said concave surface, said first surface of said cathode having a small disc of tungsten set in the center portion thereof leaving a free space under the disc for cooling purposes, the remainder of said cathode being of a refractory metal which emits thermionic electrons but which is other than tungsten.

CHESTER J. CALBICK.

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